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PICEA

(spruces)

The spruces (*Picea*) total 35 to 40 species, about half confined to China, where the exact number of intergrading species is uncertain. They are widely distributed in coniferous forests of cooler north temperate regions. They extend southward to high mountains in northern Mexico, southern Europe, Asia Minor, Himalayas, and Taiwan. Of the 7 species native in the United States, 5 are of interest in silviculture.

Thin scaly bark is characteristic. Buds are usually not resinous. The needlelike leaves, persistent up to 10 years, are borne on peglike stalks which remain on older twigs. The needles are 4-angled or in a few species flattened, stiff, and sharp-pointed.

In spring a tree bears male and ovulate strobili, the former from buds along the twig growth of the previous year and the latter terminal. The egg-shaped or cylindric cones, mostly in the upper part of the crown, mature in one season, hang down, and remain attached for some time. The many cone scales bear at the base 2 long-winged seeds. Cotyledons 4 to 15.

F–490500

ENGELMANN SPRUCE (*Picea engelmannii* Parry)

Other common names: Columbian spruce, mountain spruce, silver spruce, white spruce.

Engelmann spruce is a widely distributed species; extensive stands are found in nine western States and two Canadian provinces. Its range extends from British Columbia and Alberta, south to New Mexico and Arizona.

In the Pacific Coast region, it grows along the east slope of the Coastal Range from west central British Columbia, south along the east slope of the Cascades through Washington and Oregon to Mt. Shasta in northern California. It is only a minor component of the high elevation Pacific Coast forests.

Engelmann spruce is found in the Rocky Mountains of southwestern Alberta, south through the high mountains of northeastern Washington, northern and eastern Idaho, western Montana, northeastern Oregon, to western and central Wyoming; and in the high mountains of southern Wyoming, Colorado, northern and southern New Mexico, southeastern Arizona, and Utah. It is a major component of the high elevation forests of the Rocky Mountain region.

HABITAT CONDITIONS

Climate

Engelmann spruce grows in a climatic zone classified as cold and humid (*30*).[1] It occupies the highest and coldest forest environment in the western United States, characterized by annual temperature extremes of −50° F. and 90° plus, and heavy snowfall. Climatic data for four regions in the species' range are given in table 1.

Average precipitation exceeds 25 inches annually with only moderate or no seasonal deficiency. Summer is the driest season in the Cascades and Rocky Mountains west of the Continental Divide as far south as southern Colorado. East of the Divide and in the mountains of southern Colorado, New Mexico, Arizona, and southern Utah, late summer rainfall is heavy and winter snowfall relatively light (*2*, *30*).

Soils and Topography

In the northern Rocky Mountains, the soils are generally young, and well-defined profiles are rare. However, some of the deepest soils with the best defined profiles are found in the central Rocky Mountains under spruce.

Best growth occurs on moderately deep, well-drained silt and clay loam soils, developed from basalt, andesite, rhyolite, shale, and limestone. Alluvial soils, developed from a wide range of parent materials where an accessible water table is more important than physical properties of the soil also support good growth.

It does not make good growth on shallow, dry, coarse-textured sands and gravels, developed primarily from granitic schistic rock, and coarse sandstones, heavy clay surface soils, or saturated soils.

Along the east slope of the Coastal Range and interior valleys of southwestern British Columbia, Engelmann spruce grows at 2,500 to 3,500 feet; further south in the Cascade Mountains of Washington and Oregon, generally at 4,000 to 6,000 feet, but may be found at 8,000 feet on sheltered slopes and at 2,000 feet in cold pockets along streams and valley bottoms; and in northern California, at 4,000 to 5,000 feet (*12*, *28*).

South of the Peace River plateau in the Rocky Mountains of British Columbia and Alberta, Engelmann spruce grows at 2,500 to 6,000 feet; in the

[1] Italic numbers in parentheses refer to Literature Cited, p. 303.

TABLE 1.—*Climatological data for four regions within the range of Engelmann spruce*

Region	Average temperature			Annual precipitation	Annual snowfall	Frost-free period
	Annual	July	January			
	°F.	°F.	°F.	In.	In.	Days
Pacific Coast	35	50–55	15–20	60–160	400+	45–90
Northern Rocky Mountains	30–35	45–55	10–20	45+	250+	[1] 30–60
Central Rocky Mountains	30–35	50–55	10–15	25–35	130–350	[1] 30–60
Southern Rocky Mountains	35	50–60	15–20	25–35	200+	[1] 30–60

[1] Or even less than 30 days.

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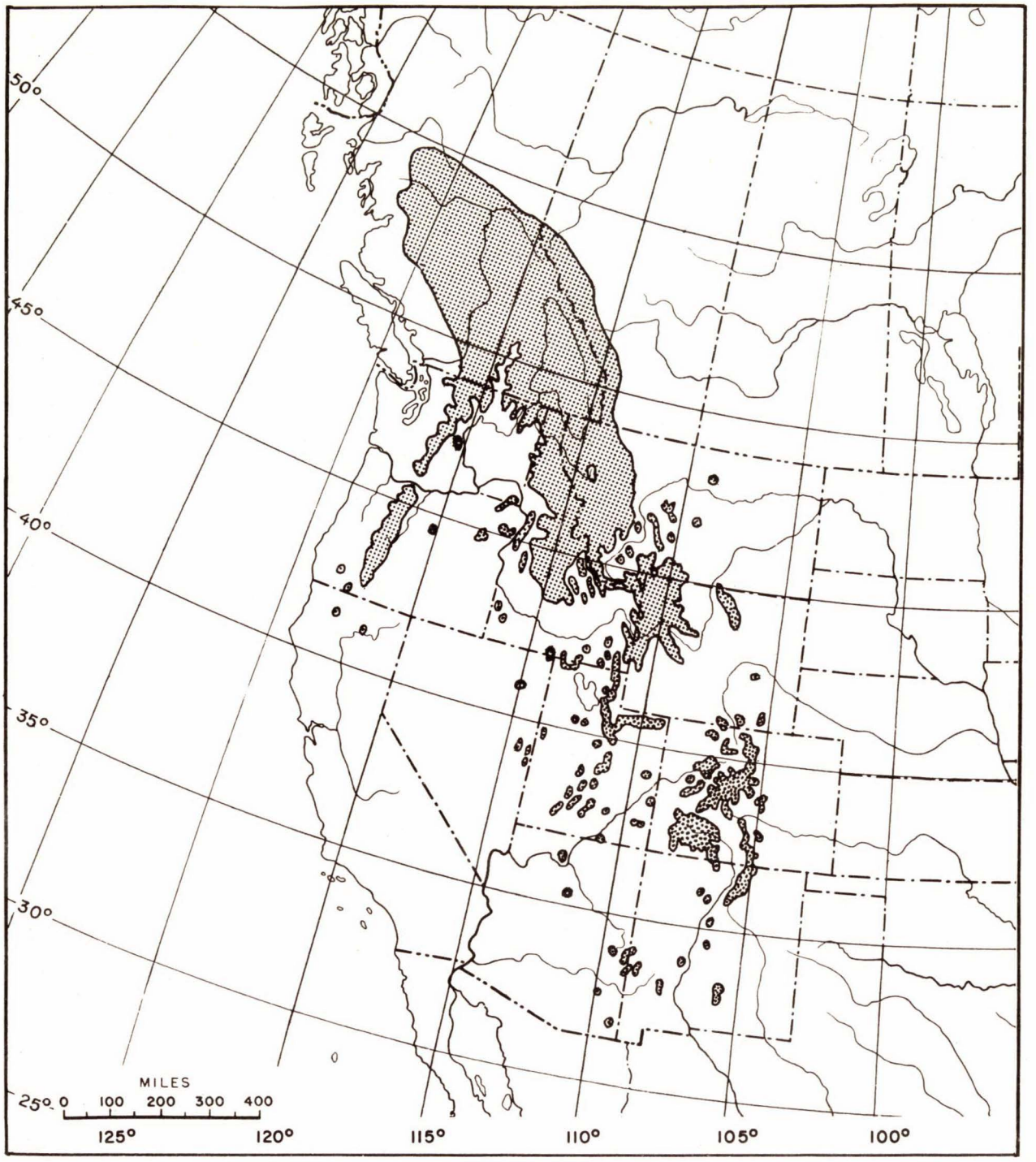

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The range of Engelmann spruce.

northern Rocky Mountains, at 2,000 to 11,000 feet. But above 6,000 to 7,500 feet it is a minor component of the stand and below 5,000 feet it is confined to moist lower slopes and cold valley bottoms (*13*, *14*).

Engelmann spruce is found at 9,000 to 11,000 feet in the central Rocky Mountains, but may extend as low as 8,000 feet along cold stream bottoms and to timberline at 11,500 feet; in the southern Rocky Mountains it grows usually at 9,500 to 11,000 feet, but may grow as low as 8,000 feet and as high as 12,000 feet (*5*, *20*).

Associated Trees and Shrubs

Engelmann spruce may be the major component in the Englemann Spruce—Subalpine Fir Type (Type 206). It grows in 14 other recognized forest types. These are:

Type number	*Type*
201	White Spruce
203	Poplar—Birch
205	Mountain Hemlock—Subalpine Fir
208	Whitebark Pine
209	Bristlecone Pine
210	Interior Douglas-Fir
212	Larch—Douglas-Fir
213	Grand Fir—Larch—Douglas-Fir
215	Western White Pine
216	Blue Spruce
217	Aspen
218	Lodgepole Pine
227	Western Redcedar—Western Hemlock
228	Western Redcedar

The composition of the forest in which Engelmann spruce grows varies with elevation, exposure, and latitude. In the Rocky Mountains and Cascades, subalpine fir is its common associate at all elevations. In Alberta, it mixes with white spruce, balsam poplar, and birch. In the northern Rocky Mountains associates at its lower limits include western white pine, western redcedar, and western hemlock; at middle elevations interior Douglas-fir, western larch, and grand fir; and at higher elevations, mountain hemlock, whitebark pine, and subalpine larch. Engelmann spruce extends to timberline forests (*13*, *14*).

In the central Rocky Mountains lodgepole pine, interior Douglas-fir, blue spruce, and aspen are associates at its lower limits and whitebark pine, bristlecone pine, and limber pine at middle and higher elevations. In association with subalpine fir, it forms the timberline forest.

In the southern Rocky Mountains, white fir, interior Douglas-fir, blue spruce, aspen, and occasionally ponderosa pine are associates at its lower limits; and corkbark fir and bristlecone pine at middle and higher elevations. It extends above corkbark and subalpine fir, forming nearly pure stands at timberline (*16*, *20*).

In the Cascades, it mixes with western white pine, western larch, grand fir, western hemlock, western redcedar, and Pacific silver fir at its lower limits; and subalpine larch, mountain hemlock, and whitebark pine form the timberline forests.

Common shrub associates include in the Northern Rockies: grouse whortleberry (*Vaccinium scoparium*), big whortleberry (*V. membranaceum*), ovalleaf whortleberry (*V. ovalifolium*) rusty skunkbrush (*Menziesia ferruginea*), alder (*Alnus* spp.), Pacific yew (*Taxus brevifolia*), elderberry (*Sambucus* spp.), and devilsclub (*Oplopanax horridus*); Central Rockies: grouse whortleberry, prickly currant (*Ribes lacustre*), and russet buffaloberry (*Lepargyrea canadensis*); Southern Rockies: Common juniper (*Juniperus communis*), and creeping hollygrape (*Odostemon repens*); and Cascades: big whortleberry, myrtle boxleaf (*Pachistima myrsinites*), false azalea (*Azaleastrum albiflorum*), beargrass (*Xerophyllum tenax*), and smooth Labradortea (*Ledum glandulosum*) (*15*, *19*, *25*). None of these are known to be indicator plants.

LIFE HISTORY

Reproduction and Early Growth

Flowering and fruiting.—Male flowers ripen and pollen is wind-disseminated in June at lower elevations and in July at higher elevations. Cones mature and seeds ripen near the end of September or early October of the first year.

Seed production.—Engelmann spruce begins bearing cones between the ages of 16 and 25 years. The maximum amount of seed is produced by dominant trees averaging 18 to 20 inches in diameter and between 200 and 250 years old (*8*, *19*). Good crops are generally borne every 2 to 6 years with light crops in more than half of the intervening years (*17*, *20*).

In a Montana study covering 22 seasons over a 45-year period, Engelmann spruce was rated a good to prolific seeder west of the Continental Divide, with the occurrence of one to seven good crops followed by one to five poor crops. But east of the Divide, spruce was rated only fair with the occurence of one to three good crops followed by two to five poor crops (*6*).

Some seed is lost by the cutting and storing of cones by the Fremont chickaree and the western chipmunk. Mice and other small rodents are known to eat the seed; but apparently the small seeds, averaging 135,000 to the pound, are easily missed by the rodents and so a large amount escapes them.

Seed dissemination.—The cones begin to open in September and most of the seed is shed by the end of October, although some continues to fall

throughout the winter. Seed is spread one-eighth mile or more by the wind. In one study during a bumper seed year, an average of 60,000 seeds per acre were disseminated into a clear-cut area a distance of 10 chains from standing green timber. Seedfall in the uncut stand averaged 950,000 seeds per acre (*26*).

Seedling development.—Engelmann spruce seedlings become established on nearly every type of seedbed found under forest conditions—mounds of upturned soil from wind-thrown trees, sliding soils on steep slopes, decaying and moss covered stumps and logs, and the usual forest litter (*15*, *19*, *27*). Engelmann spruce will survive at lower light intensities than its associates lodgepole pine, interior Douglas-fir, and western white pine, but cannot survive deep shade as well as subalpine fir. Nor will it survive strong sunlight as well as lodgepole pine. It is more resistant to low temperatures than interior Douglas-fir, lodgepole pine, ponderosa pine, western white pine, and bristlecone pine, but less so than subalpine fir, limber pine, and whitebark pine. But it is no more resistant to drought than its associates; its shallow, slow growing root system causes the seedling to be susceptible to high temperatures (*4*).

Planted Engelmann spruce trees survive very poorly at high elevations in Colorado when exposed to full sunlight. Exposure to high light intensity may interfere with photosynthesis or some other physiological process (*24*).

The early growth of Engelmann spruce is slow (*15*). In Colorado, roots of the most vigorous seedlings penetrated less than 3 inches in an undisturbed seedbed in 1 year (*23*). Penetration was not much greater in mineral soil.

Shoot growth is equally slow. In Colorado, 5-year-old seedlings averaged less than 1 inch in height under natural conditions, 2 inches in a clear cutting, and from 2 to 3 inches in a partial cutting. At the end of 7 years, seedlings under natural conditions had grown only 1 inch; those left after clear cutting, 3 to 4 inches; and those left after partial cutting, 2 to 4 inches (*23*).

In a closed forest in Wyoming, Engelmann spruce 4 to 6 feet tall were found to be from 45 to 75 years old. Subalpine firs of the same height range were 35 to 50 years old (*19*).

The early growth of Engelmann spruce is less affected by competition for growing space than that of its more intolerant associates. In a study of seed spot density in northern Idaho, diameter growth of spruce seedlings after 17 years was only slightly greater on thinned seed spots, and height growth was unaffected by the thinning. In contrast, diameter and height growth of western white pine increased significantly as the number of seedlings per seed spot decreased (*7*).

Vegetative reproduction.—Layering is common near the upper limit of tree growth where the species assumes a characteristic dwarfed or prostrate form, but it is insignificant in the establishment and maintenance of closed forest stands (*19*).

Sapling Stage to Maturity

Growth and yield.—Engelmann spruce is one of the largest of the high mountain species. Under favorable conditions, it will average 18 to 30 inches in diameter and 80 to 100 feet in height (*9*). Large, mature dominants may exceed 40 inches in diameter and average 150 to 160 feet in height (*15*). The largest tree on record is 19 feet, 11 inches in circumference at breast height and 104 feet tall (*1*).

Engelmann spruce is a long-lived tree, maturing in about 300 years. Trees 16 to 22 inches in diameter are often 350 to 450 years old, and trees over 500 years old are not uncommon. Engelmann spruce has the capacity to make good growth at advanced ages—it will continue to grow steadily in diameter for 300 years if given sufficient growing space.

Average volume per acre in old-growth spruce—fir stands may be practically nothing at timberline, 5,000–15,000 board feet on poor sites, and 25,000–40,000 board feet on better sites. Volumes as high as 80,000–100,000 board feet have been reported (*20*, *21*, *29*). Average annual growth in virgin spruce—fir forests will vary up to more than 300 board feet per acre.

Frequently the structure of old-growth Engelmann spruce—subalpine fir forests is nearly pure spruce in the overstory with fir predominating in the understory. In old-growth spruce—fir forests in southern Wyoming, Engelmann spruce always makes up more than 70 percent of the total basal area, and often more than 90 percent (*19*).

Reaction to competition.—Engelmann spruce is rated tolerant in its ability to endure shade. It is definitely more shade enduring than interior Douglas-fir, western white pine, lodgepole pine, western larch, or ponderosa pine; but less so than subalpine fir, its most common associate throughout much of its range (*3*).

The Engelmann spruce—subalpine fir type forms a stable or near-climax forest vegetation throughout much of the area it occupies. Many spruce—fir forests differ from true climax forests in that they are not all-aged but are even-aged [2] (*15*).

Following destruction on northerly exposures, Engelmann spruce and subalpine fir usually re-

[2] The comparative scarcity of all-aged stands is believed by some ecologists to be due to catastrophic fires which preceeded the establishment of the mature spruce forests present in the Rocky Mountains today.

turn at once. On southerly exposures, such species as aspen, interior Douglas-fir, lodgepole pine, and western white pine may become established initially, but are eventually replaced by the more shade tolerant spruce and fir (*15*, *20*). Engelmann spruce may be suppressed under the latter conditions or in dense virgin stands for 50 to 100 years, but it will respond quickly to release and soon outgrow its common associates (*8*).

Principal enemies.—Engelmann spruce is susceptible to windthrow, especially after partial cutting. A shallow root system is common on bogs or in soils underlain by impervious rock or clay subsoils, but on deep, porous soils the root system may extend down more than 8 feet.

Old-growth spruce is especially susceptible to attacks by the spruce bark beetle (*Dendroctonus engelmannii*) (*18*). On the White River Plateau in Colorado an epidemic infestation destroyed 5 billion board feet before being controlled in 1952. The defoliating spruce budworm (*Choristoneura fumiferana*) is the only other potentially dangerous insect enemy.

The most common diseases of Engelmann spruce are caused by wood rotting fungi: *Fomes pini*, *Polyporus circinatus*, *Coniophora ceribella*, *Peniophora luna*, and *Stereum sanguinolentum* (*10*). Recent studies have linked two brown rots, *F. pinicola* and *C. puteana*, and spruce broom rust *Peridermium coloradense*, with windthrow (*22*).

The thin bark and persistence of dead lower limbs makes Engelmann spruce especially susceptible to destruction or severe injury by fire. Most root and trunk rots in old-growth stands appear to be associated with fire injury.

RACES AND HYBRIDS

There are no recognized races or geographical varieties of Engelmann spruce (*19*). However, natural crosses between Engelmann and Colorado blue spruces have been observed in the Central Rocky Mountains and natural hybridization between Engelmann and Sitka spruces has been reported in northern British Columbia and southwestern Alaska. Fairly extensive natural crossings with white spruce occur where the ranges of the two species meet in northwestern Montana, central British Columbia, and southwestern Alberta (*8*, *11*). In those areas, cone size and conformation of cone scales are exceedingly variable between Engelmann and white spruces. Western white spruce is probably a product of the natural hybridization between Engelmann and white spruce (*31*). Hybridization of Engelmann spruce with Colorado blue, white, and Sitka spruces can also be made by controlled pollination (*8*, *11*, *31*).

Revised from "Silvical Characteristics of Engelmann Spruce," by R. R. Alexander. U.S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta., Sta. Paper 31. 1958.

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